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Monterey, California

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NET TECHNICAL ASSESSMENT

By

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Washington, DC 20301

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MONTEREY, CALIFORNIA

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Report discusses how to perform net technical assessments and the purposes for which such assessments can be used. Author discusses how such assessments are a part of the strategic planning process for government.

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I. INTRODUCTION

The present and near term military balance of power between the U.S. and the Soviet Union can be expressed in a variety of net assessments. One can examine the strategic nuclear balance, the conventional balance in Europe, the maritime balance, and many others. Such assessments are essential not only for policy making but for arms control purposes and future force structure planning. However, to project the future military balance, one must include an assessment of the base technological balance between the U.S. and the Soviet Union.

The West has traditionally relied on a technological edge in weaponry to offset the numerical advantages of the Soviet Union and its surrogates. The foundations of high-tech weaponry lie in the base technologies. Although the U.S. clearly benefits from the technological developments of its allies, this paper focuses on the U.S. and the Soviet Union. Its objective is to identify the critical issues of the technological balance that affect the future military balance of power.

Figure 1 illustrates the interdependence of a nation's technology base, its force objectives, and fielded weapons. While the focus is on the technological bases of the U.S. and the Soviet Union, such an assessment must address these relationships.

A variety of measures can be used in the arena of net assessments. In general, they can be categorized as either "input" or "output" measures. An input measure is some characteristic of a nation's effort to affect the balance of

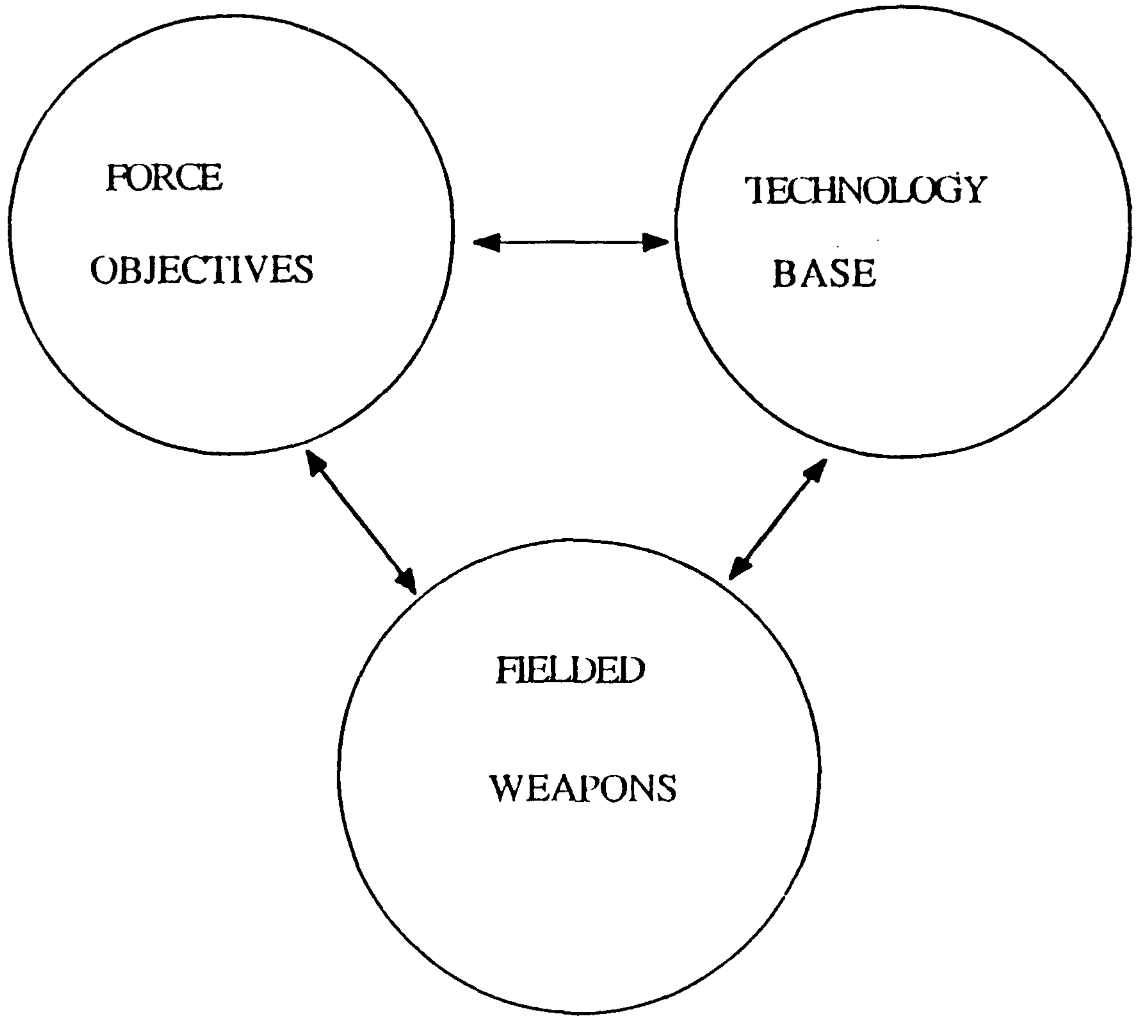


Figure 1

interest; it is related? (an evaluation of) to the resource investment. An output measure is a direct reflection of the balance; it is an evaluation of the products of the investments. I will first discuss the utility of input measures in a net technical assessment.

A-1

II. INPUT MEASURES

A net technical assessment input measure evaluates a nation's resources expended on developing military technologies. Examples include R&D costs as well as manpower involved in military R&D. Input measures are useful for both a macro analysis of the complete technology picture and for comparing specific technology areas.

On a macro scale, manpower and monetary comparisons provide an assessment of the broad base technology investment. The drawbacks of using these measures lie in the asymmetries between the U.S. and Soviet economies. Soviet civilian industry produces little (if any) state of the art or marketable goods, while the military industry produces high technology weapons. Thus, Soviet input measures are essentially derived from government expenditures. On the other hand, the U.S. civilian industry is a world leader in high technology goods. The highly competitive marketplace and the search for knowledge in the fundamental sciences (much of which is government subsidized) have been the driving forces. Much of the technology developed by the civilian industry has military applications, especially in the areas of high speed computers, microelectronics, and computer software. Although I do not suggest that there is a distinct cutoff between civilian and military industry, or that government funding as well as government trained personnel are not present in the private sector, U.S. civilian industry contributes greatly to the development of military technologies. Hence, U.S. input measures should include not only government investment but corporate investment as well.

This asymmetry makes direct comparisons of input measures difficult. If one ignores U.S. corporate investment, then the input measure is biased. If one includes corporate investment, then deciding which corporate investments should be included is difficult.

In budget testimony to Congress, the Under Secretary of Defense for Research and Engineering (USDR&E) used a comparison of government research, development, testing, and evaluation (RDT&E) expenditures to influence programming decisions. Figure 2.1 (Ref 1) is an example.

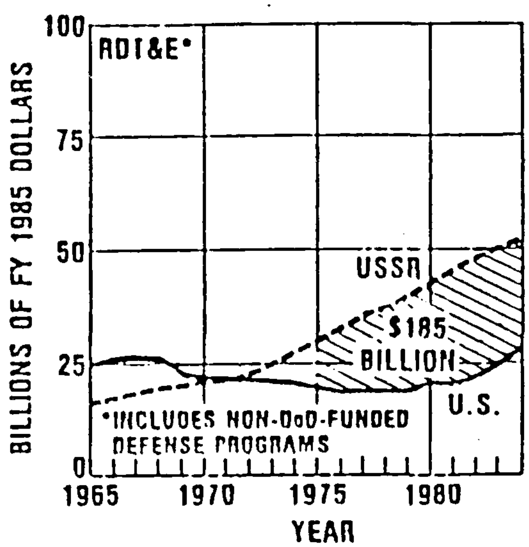
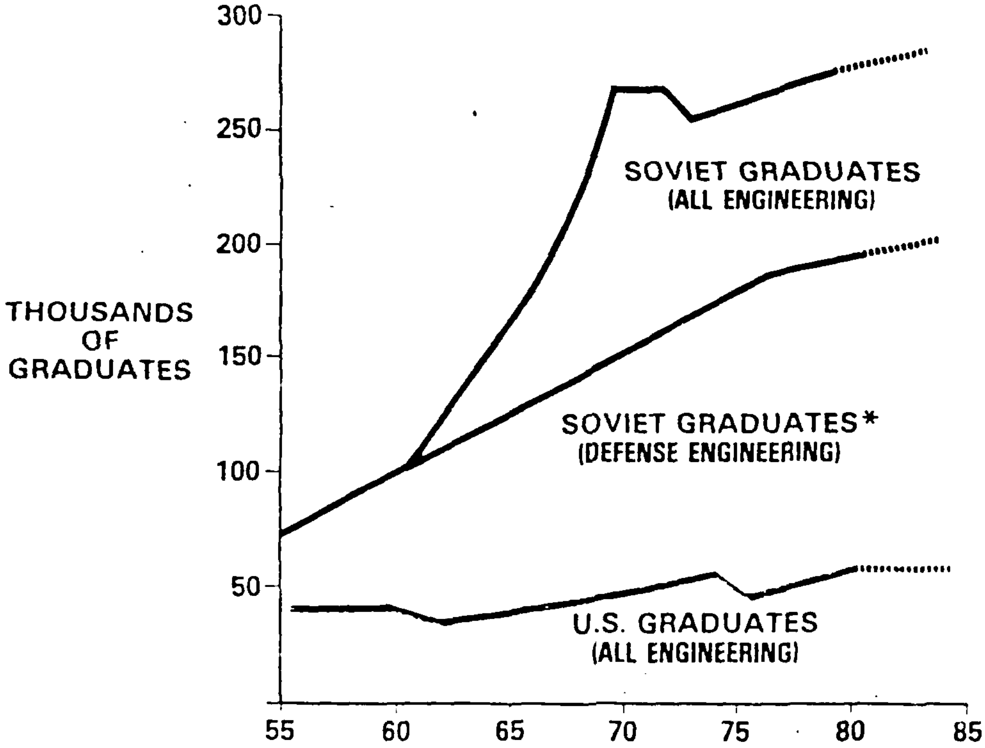


Figure 2.1

The impression obtained from this figure is that the U.S. is "behind" in technology investment. The text associated with this figure states that "Soviet RDT&E has been increasing in real terms at an average of about 7% per year for 20 years (doubling in real terms every 10 years) and is growing more than other Soviet military investments. In the past ten years the dollar cost of Soviet R&D activities have been estimated $185 billion more than the U.S. While there is significant uncertainty in these estimates, this long term trend cannot be allowed to continue." In this case, the USDR&E chose not to estimate U.S. corporate investment. The audience is required to estimate that contribution.

Manpower comparisons have been used by the JCS in testimony to Congress. One specific measure presented is the number of Bachelor of Science in Engineering graduates. Figure 2.2 (Ref 2) is an example. Again, the impression is that the U.S. is "behind." The text associated with this figure is: "Today the U.S. has about 600,000 full-time scientists and engineers engaged in all types of R&D, the Soviet Union about 900,000. Although the productivity of the typical Soviet scientific worker may still be less than his U.S. counterpart, there is a trend toward parity. More worrisome still, the U.S. educational system is yielding only about 50,000 engineering graduates per year, and relatively few of them are moving into defense related work. The Soviet Union, on the other hand, graduates over 250,000 engineers per year, of which some 200,000 move into military oriented work.

UNDERGRADUATE ENGINEERING U.S. AND SOVIET



* COMPARABLE DATA FOR U.S. DOES NOT EXIST
SOURCE: NATIONAL CENTER FOR EDUCATIONAL STATISTICS

Figure 2.2

These trends, depicted in..., could have a profound effect, over time, on the U.S. ability to maintain its technological lead."

The implications of these figures are significant. The measure includes both government as well as corporate "investment" in technology. The Soviets are investing nearly an order of magnitude more engineers into their technology base. If the Soviet Union could mobilize this "army" with Western innovation through glasnost, the technological balance would no longer show a Western advantage.

In micro-scale, manpower and "dollar" investment comparisons can provide assessments of not only the relative magnitude of U.S. and Soviet efforts in a particular technology but also an indication of the relative importance each nation places on that technology. For example, if the Soviets significantly increased RDT&E rubles spent on a specific ASW technology, one could conclude that they consider this particular technology promising. Unfortunately, specific technology investment comparisons are rarely found in open literature. Instead one must rely on classified publications that include intelligence resources.

III. OUTPUT MEASURES

In the context of net technical assessments, an output measure is an indicator of the current state of a nation's technology base. It also reflects the conversion of input measures into usable products (technology). The primary utility of technical assessment output measures lies in comparisons of specific technologies. Although one often hears of the technological balance in terms of which nation is "ahead technologically," this macro approach is inappropriate for output measures. Instead, one must first identify the key military technologies (both present and future), then compare the individual technologies. For this discussion, I define a key military technology as one that currently affects, or could in the future affect, the military balance between the U.S. and the Soviet Union.

How, then, are these key military technologies identified? There are many possible approaches. Conceptually, one could classify them into two categories: A "reverse" engineering approach, and a technology exploration approach. In a reverse engineering approach, either a present or future force structure, mission area, or specific weapons system is identified and then work backward to determine what technologies are involved. A technology exploration approach is primarily focused on emerging technologies. In this case, a technology is selected, then brainstormed, to see if a significant military application can be found. If significantly improved or new weapons systems can be envisioned a result of applying this technology, then it would be identified as a "key military technology."

The primary pitfall in attempting to identify key military technologies is "mirror imaging." The force structures and capabilities of the U.S. and the Soviet Union reflect unique national objectives, philosophies, and resources. What may be considered an important force characteristic in the West may not apply to the Russian mindset. The converse is also true. An example of this dichotomy is submarine design. The Soviet Union has expended a great deal of effort to develop manufacturing techniques for titanium hulled submarines. These submarines can dive much deeper than those in Western navies. The U.S. Navy, in particular, maintains that such a capability is not worth the enormous expense (It would be much more expensive for the U.S. to build a titanium hulled submarine than it has cost the Soviets). It is probably safe to say that from both the U.S. and the Soviet Navy's perspective, each considers itself "correct." The question is: Is the titanium hull construction capability a "key military technology"? The answer to this question depends on one's perspective: To a Soviet submariner, probably; to an American submariner, probably not. Certainly, such a capability is important to at least one of the nation's in question, and hence, it would seem appropriate to include these "disputed" technologies on a key military technology list.

In budget testimony to Congress, both the USDR&E and the JCS use the output measure "key military technologies" in the form of technology balance charts. These technology balance charts have been used by the USDR&E in testimony supporting the FY 83 and subsequent defense budgets. They have been used by both the JCS and the USDR&E through FY-87. Comparisons between the charts used by these two organizations indicate that they do use the same charts. These charts have not been produced by USDR&E or the USDA since that time, but a similar chart for deployed military systems did appear in the 1988 edition of Soviet Military Power (Ref 3).

Figure 3.1 (Ref 4) is an example. The text associated with this figure is: "The importance of technology has never been more obvious than it is today. Yet, as figure... indicates, the U.S. lead in several key technologies is slipping. Strong U.S. and allied technological bases must be maintained if their qualitative lead in fielded systems is to be retained."

The listed basic technology areas are general enough that comparisons can be made on an unclassified level. Within these general areas, however, if one desired to compare the status of specific technologies, then classified sources would likely be involved. I suggest it is unlikely that the classified literature would contradict the general conclusions presented in these technology charts.

If, as noted, the U.S. lead in several key technologies is slipping, then one would expect to see a trend in the listed technologies that favored the Soviet Union. Figure 3.2 presents a summary of the technology charts presented by the JCS and USDR&E to Congress from FY 83 through FY 88 (Ref 4-9). Note that Automated Controls was dropped from the list in FY 86. Also, Electronic Warfare was added in FY 85 only to be replaced by Robotics in FY 87. In addition, Chemical Warfare was added in

Relative US–Soviet Standing In the Twenty Most Important Basic Technology Areas*

Basic Technologies	*US Superior*	*US-Soviet Equal*	*Soviet Superior*
1. Aerodynamics/Fluid Dynamics		X	
2. Computers & Software	◄ X		
3. Conventional Warheads (including all chemical explosives)		X ►	
4. Directed Energy (laser)		X	
5. Electro-Optical Sensor (including infrared)	X		
6. Guidance & Navigation	X ►		
7. Life Sciences (human factors/biotechnology)	X ►		
8. Materials (lightweight, high strength, high temperature)	X ►		
9. Micro-Electronic Materials & Integrated Circuit Manufacturing	X		
10. Nuclear Warheads		X ►	
11. Optics		X ►	
12. Power Sources (mobile) (includes automated control)		X	
13. Production/Manufacturing (includes automated control)	X ►		
14. Propulsion (aerospace and ground vehicles)	X ►		
15. Radar Sensor	X ►		
16. Robotics and Machine Intelligence	X		
17. Signal Processing	X		
18. Signature Reduction	X		
19. Submarine Detection	X		
20. Telecommunications (includes fiber optics)	X		

* The list is limited to 20 technologies, which were selected with the objective of providing a valid base for comparing overall US and USSR basic technology. The list is in alphabetical order. These technologies are "on the shelf" and available for application. (The technologies are not intended to compare technology level in currently *deployed* military systems.)

The technologies selected have the potential for significantly *changing* the military capability in the next 10 to 20 years. The technologies are not static; they are improving or have the potential for significant improvements; new technologies may appear on future lists.

The arrows denote that the relative technology level is *changing* significantly in the direction indicated.

The judgments represent overall consensus for each basic technology area. The USSR may be superior in some of the subtechnologies making up each basic technology.

These average assessments can incorporate a significant variance when individual components of a technology are considered.

As of 30 September 1986

Figure 3.1

FY 85 and then was replaced by Life Sciences in FY 87.

Of significant interest are those technologies where the U.S. does not have a lead or its lead is clearly slipping. Based on Figure 3.2, I would place the following technologies on this "danger" list: Aerodynamics/Fluid Dynamics; Conventional Warheads; Directed Energy; Nuclear Warheads; Optics; and Mobile Power Sources. This analysis tends to support the JCS claim that the U.S. technological lead is indeed slipping in several key areas.

TECHNOLOGY OF AERODYNAMICS/ FLUID DYNAMICS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83		X	
FY 84		X	
FY 85		X	
FY 86		X	
FY 87		X	
FY 88		X	

Figure 3.2
(Sheet 1 of 22)

TECHNOLOGY OF COMPUTERS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X		
FY 86	<----X		
FY 87	X---->		
FY 88	<----X		

Figure 3.2
(Sheet 2 of 22)

TECHNOLOGY OF SOFTWARE

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X		
FY 86	<----X		
FY 87	X---->		
FY 88	<----X		

Figure 3.2
(Sheet 3 of 22)

TECHNOLOGY OF CONVENTIONAL WARHEADS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83			X
FY 84			X
FY 85		X	
FY 86		X	
FY 87		X	
FY 88		X ----->	

Figure 3.2
(Sheet 4 of 22)

TECHNOLOGY OF DIRECTED ENERGY

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83		X	
FY 84		X	
FY 85		X	
FY 86		X	
FY 87		X	
FY 88		X	

Figure 3.2
(Sheet 5 of 22)

TECHNOLOGY OF ELECTRO-OPTICS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87	X		
FY 88	X		

Figure 3.2
(Sheet 6 of 22)

TECHNOLOGY
OF
GUIDANCE/NAVIGATION

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87	X		
FY 88	X---->		

Figure 3.2
(Sheet 7 of 22)

TECHNOLOGY OF CHEMICAL WARFARE

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83			
FY 84			
FY 85			X
FY 86			X
FY 87	X (LIFE SCIENCES)		
FY 88	X---->		

Figure 3.2
(Sheet 8 of 22)

TECHNOLOGY OF STRUCTURAL MATERIALS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83		<----X	
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87	X---->		
FY 88	X---->		

Figure 3.2
(Sheet 9 of 22)

TECHNOLOGY OF MICROELECTRONICS MANUFACTURING

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X---->		
FY 86	X		
FY 87	X		
FY 88	X		

Figure 3.2
(Sheet 10 of 22)

TECHNOLOGY OF NUCLEAR WARHEADS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83		X	
FY 84		X	
FY 85		X	
FY 86		X	
FY 87		X	
FY 88		X---->	

Figure 3.2
(Sheet 11 of 22)

TECHNOLOGY OF OPTICS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87		X	
FY 88		X---->	

Figure 3.2
(Sheet 12 of 22)

TECHNOLOGY OF MOBILE POWER SOURCES

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83			X
FY 84		X	
FY 85		X	
FY 86		X	
FY 87		X	
FY 88		X	

Figure 3.2
(Sheet 13 of 22)

TECHNOLOGY OF AUTOMATED CONTROL

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85		X	
FY 86			
FY 87			
FY 88			

Figure 3.2
(Sheet 14 of 22)

TECHNOLOGY
OF
PRODUCTION/MANUFACTURING

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X		
FY 86	X		
FY 87	X		
FY 88	X---->		

Figure 3.2
(Sheet 15 of 22)

TECHNOLOGY OF AERONAUTICAL PROPULSION

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X		
FY 85	X		
FY 86	X---->		
FY 87	X---->		
FY 88	X---->		

Figure 3.2
(Sheet 16 of 22)

TECHNOLOGY OF RADAR SENSOR

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87	X---->		
FY 88	X---->		

Figure 3.2
(Sheet 17 of 22)

TECHNOLOGY
OF
ELECTRONIC WARFARE

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83			
FY 84			
FY 85	X		
FY 86	X---->		
FY 87	X (ROBOTICS)		
FY 88	X		

Figure 3.2
(Sheet 18 of 22)

TECHNOLOGY
OF
SIGNAL PROCESSING

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X		
FY 85	X		
FY 86	X		
FY 87	X		
FY 88	X		

Figure 3.2
(Sheet 19 of 22)

TECHNOLOGY OF STEALTH

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X		
FY 86	X		
FY 87	X		
FY 88	X		

Figure 3.2
(Sheet 20 of 22)

TECHNOLOGY OF SUB DETECTION/QUIETING

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X---->		
FY 84	X---->		
FY 85	X---->		
FY 86	X---->		
FY 87	X---->		
FY 88	X---->		

Figure 3.2
(Sheet 21 of 22)

TECHNOLOGY OF TELE-COMMUNICATIONS

	U.S. SUPERIOR	EVEN	U.S.S.R. SUPERIOR
FY 83	X		
FY 84	X		
FY 85	X		
FY 86	X		
FY 87	X		
FY 88	X		

Figure 3.2
(Sheet 22 of 22)

IV. TECHNOLOGY TRANSFER

A discussion of the technological balance between the U.S. and the Soviet Union would be incomplete if it did not include the subject of technology transfer. Since this subject does not fall neatly into the categories of either input or output measures, it is treated separately here.

In the context of a net technical assessment, the issue is not one of prevention, but damage assessment. The Soviet's massive effort in this area includes use of the KGB and GRU intelligence organizations; the facilities of the Ministry of Foreign Trade in Western countries, including state owned businesses and corporations; the State Committee on Science and Technology, which arranges government science and technology agreements; and the Academies of Science and their Institutes, which have contacts with Western universities and research institutes, both directly and through technical conferences (Ref 10).

Despite efforts by the U.S. and its allies to slow down the rate of technology transfer, the Soviet Union will continue to obtain some of our vital military technology. The factors that affect the impact of technology transfer include:

1. The stage of development at which the Soviets acquire the technology.

2. Which country can most quickly adapt a new technology to field a new or significantly improved weapons system.

Although not all inclusive, these two factors provide a framework for discussing the technology transfer issue.

These factors are interrelated. Figure 4.1 illustrates a simplified flowpath of U.S. technology from inception to a fielded weapon. The five general stages are:

1. Idea/Discovery Stage: In this stage, a research team either formulates a new theory or discovers a new phenomenon that warrants further research. This team could be in a corporation, university, or within a government agency.

2. Verification/Demonstration Stage: In this stage, the theory is demonstrated experimentally, or the phenomenon is verified independently by several research teams.

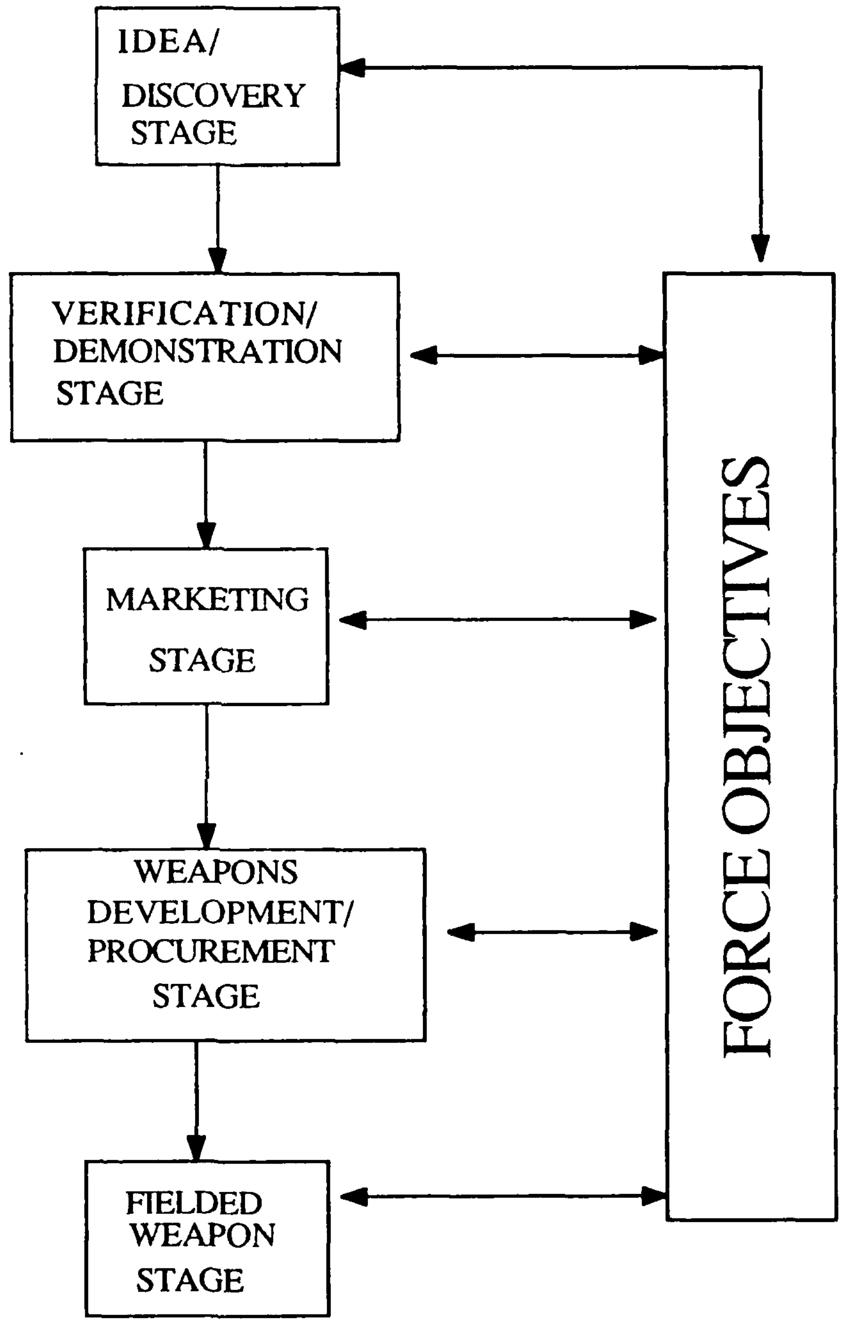
3. Marketing Stage: In this stage, the validated technology is "sold" to a DOD activity as being of possible use in a new/improved weapons system. If the project had not previously been associated with a government agency, it is in this stage that a classification or export controls could be assigned.

4. Weapons Development/Procurement Stage: In this stage, the technology is incorporated into the procurement process. It is here that production and manufacturing considerations enter.

5. Fielded Weapon Stage: In this stage, the technology is fielded as part of a weapons systems.

Although not a technology development stage itself, Force Objectives was included in this figure to emphasize the concept previously illustrated in Figure 1; technological development influences, and is influenced by, force objectives.

The primary difficulty in assessing the role of technology transfer on the base technological balance stems from the


IDEA/
DISCOVERY
STAGE
VERIFICATION/
DEMONSTRATION
STAGE
MARKETING
STAGE
WEAPONS
DEVELOPMENT/
PROCUREMENT
STAGE
FIELDED
WEAPON
STAGE
FORCE OBJECTIVES

fundamental differences in the philosophy of weapons development in the U.S. and the Soviet Union. The U.S. tends to wait for "technological breakthroughs" before procuring a new weapons system while the Soviets rely on frequent, incremental improvements in their weapons systems.

It would seem, then, that much of the "damage" of technology transfer occurs in the later stages of technology development such as the Weapons Development/Procurement Stage. From this perspective, new U.S. hardware, both military and civilian, is a "prime Soviet target." Acquisition of such hardware not only directly assists their military forces but also contributes to their base technology. By "reverse engineering" U.S. hardware, the Soviets can identify the production tools and processes necessary to manufacture the particular piece of equipment. If these tools can also be acquired, then this new hardware technology essentially becomes a part of their technology base.

On the other end of the spectrum of technology targets is U.S. research in the fundamental sciences. As noted, several Soviet organizations can acquire this knowledge quite "legally." Although it might seem that U.S. innovation would win a particular technology race, Soviet acquisition of the new technology at all stages of its development would enable parallel development of this new technology, with the U.S. "providing assistance" as required.

V. CONCLUSIONS

A net technical assessment must include a variety of parameters. These include manpower and monetary input measures, key military technology output measures, and a damage assessment of technology transfer. Although a few defense agencies have addressed these parameters individually, a complete technology assessment has not been attempted. The complexities of performing such an assessment have been identified, and at first glance, appear rather prohibitive.

The offices of the USDR&E and the JCS have intermittently brought these issues to the attention of Congress. Although these offices have shown that the U.S. maintains a technological lead in most areas, there are several key technology areas where U.S. and the Soviet Union are even or the U.S. is losing its lead. This fact, combined with a perceived imbalance of R&D investment expenditures, might suggest that these estimates were driven by programming considerations. Of particular interest is the fact that two key technologies of SDI are included on the technology "danger list."

On the other hand, if the technology estimates are "unbiased," then a disturbing trend is evident. The loss of technological leads in several key areas combined with an extraordinary mismatch in graduating engineers suggests that these estimates are indicative of a potentially profound change in the future military balance of power.

Although a few defense agencies have addressed the issues of the technological balance of power individually, a complete technology assessment has not been attempted. The complexities of performing such an assessment have been identified, and at first glance, appear to be rather prohibitive.

It is imperative that our nation's military and civilian leaders identify the force requirements of our future military forces. These forces must be consistent not only with U.S. national objectives, but must address the challenges of our potential adversaries. Part of this process must include a projection of feasible technologies that could be deployed in future weapons systems. The cornerstone of these future weapons is basic technology. Unless the U.S. and its allies are willing to trust the future military balance of power to "lucky guesses," a coherent assessment of the base technological balance must be performed.

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3. <u>Soviet Military Power,</u> 1988.

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9. United States Military Posture FY 1987; Organization of the Joint Chiefs of Staff.

10. The FY 1987 Department of Defense Program for Research and Development; Statement by the Under Secretary of Defense, Research and Engineering to the 99th Congress, Second Session 1986.

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